CLAIMS FOR U.S. APPLICATION SERIAL NO. 09/404,122
(CORRESPONDING INTERNATIONAL PUBLICATION NO. WO 01/22276)

"SYSTEM AND METHOD FOR PREDICTION OF BEHAVIOR OF COMPLEX SYSTEMS"

2. A computer-based method for prediction of behavior in a financial system using financial return data, the method comprising the steps of:

inputting the financial return data and a set of independent variables corresponding to properties of the financial system into a computer, wherein the financial return data comprises a plurality of data points having multiple co-variances which are collected over time;

generating a co-variance matrix comprising the steps of:

(a) defining a first loading matrix having elements comprising a first subset of independent variables within the set of independent variables, the first subset comprising a least quantity of independent variables estimated to fit the financial return data;

(b) determining a goodness-of-fit to the financial return data according to a selected goodness-of-fit criterion for each independent variable within the first loading matrix;

(c) culling each independent variable within the first loading matrix whose presence or elimination fails to change the goodness-of-fit to produce a reduced element first loading matrix;

(d) defining a next loading matrix containing a larger subset of independent variables than the first loading matrix;

(e) adding the next loading matrix to the reduced element first loading matrix to define a combination of loading matrix elements;

(f) determining the goodness-of-fit to the financial return data for the combination of loading matrix elements;

(g) culling each independent variable of the combination of loading matrix elements whose presence or elimination fails to change the goodness-of-fit; and

(h) repeating steps (d) through (g) until the goodness-of-fit to the financial return data meets the selected goodness-of-fit criterion in a final iteration, wherein the resulting co-variance matrix comprises the combination of loading matrix elements wherein the number of off-diagonal, non-zero loading matrix elements in the co-

EXHIBIT C
DECLARATION OF ROBERT PIÑA

variance matrix is minimized and_wherein the remaining independent variables comprise the smallest subset of independent variables that fits the financial return data.

3. The computer-based method of claim 2, wherein the financial return data comprises daily returns of financial securities.

4. The computer-based method of claim 3, wherein the daily returns comprise a linear combination of unknown factors and a part that fluctuates independently corresponding to noise, according to the relationship

$$X_\alpha = \sum_{\beta=1}^{k} \Lambda_{\alpha,\beta} f_\beta + N_\alpha ,$$

where α and β are financial securities, X_α is the daily return for financial security α, f_β is an unknown factor, $\Lambda_{\alpha,\beta}$ is the loading matrix, and N_α is the noise.

5. The computer-based method of claim 2, wherein the goodness-of-fit is the logarithm of the likelihood function according to the relationship

$$L = -2 \ln \Pr(D|M) = \sum_n w_n \left(\ln\|V_n\| + x_n \bullet V_n^{-1} \bullet x_n \right),$$

where L is the log-likelihood function, V is the covariance matrix, $\Pr(D|M)$ is a goodness-of-fit quantity measuring the probability of data D given model M, and w_n is an arbitrary weight.

6. The computer-based method of claim 2, wherein the least quantity of independent variables corresponds to zero unknown factors and a covariance matrix consisting of a diagonal.

8. A system for prediction of behavior in a financial system using financial return data, the system comprising:

a computer having an input for receiving the return data comprising a plurality of data points having multiple co-variances collected over a period of time and a set of independent variables corresponding to properties of the financial system;

computer software contained within the computer for performing a plurality of iterations, each iteration comprising identifying a loading matrix having elements comprising a subset of independent variables within the set of independent variables and determining a goodness of fit to the financial return data according to a selected goodness-of-fit criterion for each independent variable of the subset, eliminating each independent variable within the subset whose presence or elimination fails to change the goodness-of-fit at the predetermined minimum level, and combining, after the plurality of iterations, remaining independent variables to identify the smallest subset of independent variables that fits the financial return

data to produce a co-variance matrix from a combination of loading matrices wherein the remaining independent variables correspond to loading matrix elements remaining after minimizing the number of off-diagonal, non-zero loading matrix elements;

wherein the plurality of iterations utilizes increasingly larger subsets of independent variables.

9. The system of claim 8, wherein the financial return data comprises daily returns of financial securities.

10. The system of claim 9, wherein the daily returns comprise a linear combination of unknown factors and a part that fluctuates independently corresponding to noise, according to the relationship

$$X_\alpha = \sum_{\beta=1}^{k} \Lambda_{\alpha,\beta} f_\beta + N_\alpha ,$$

where a and ß are financial securities, X_a is the daily return for financial security a, $f_ß$ is an unknown factor, $\Lambda_{a,ß}$ is the loading matrix, and N_a is the noise.

11. The system of claim 8, wherein the goodness-of-fit is the logarithm of the likelihood function according to the relationship

$$L = -2 \ln \Pr(D|M) = \sum_n w_n \left(\ln\|V_n\| + x_n \bullet V_n^{-1} \bullet x_n \right),$$

where L is the log-likelihood function, V is the covariance matrix, $\Pr(D|M)$ is a goodness-of-fit quantity measuring the probability of data D given model M and w_n is an arbitrary weight.

12. The system of claim 8, wherein the least quantity of independent variables corresponds to zero unknown factors and a covariance matrix consisting of a diagonal.

14. A computer-based method for prediction of behavior in a financial system comprising:

estimating a multi-variable covariance matrix of the financial system comprising a plurality of variables and a plurality of factors using a subset of the plurality of factors, wherein the subset comprises the minimum number of factors capable of describing the plurality of variables, wherein the subset is selected by iteratively modeling each variable as a linear combination of unknown factors and a noise factor starting with zero factors and adding one factor with each iteration until a model is identified for which no further improvement occurs.

15. The computer-based method of claim 14, wherein improvement is determined by a goodness-of-fit criterion comprising a log-likelihood function which is minimized using a conjugate gradient.

16. The computer-based method of Claim 14, wherein each iteration comprises the steps of:

defining a loading matrix containing a group of factors;

minimizing the number of off-diagonal, non-zero factors in the loading matrix;

wherein the covariance matrix is estimated by combining the loading matrices having a minimized number of off-diagonal, non-zero factors.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In Re Application of	)	FOR: SYSTEM AND METHOD FOR PREDICTION OF BEHAVIOR OF COMPLEX SYSTEMS
Amos Yahil, et al.	)	
Serial No.: 09/404,122	)	Group Art Unit: 2123
Filed: September 23, 1999	)	

DECLARATION OF RICHARD C. PUETTER

I, Richard C. Puetter, state that:

1. I am over the age of eighteen and competent to make this declaration.

2. I received a Doctor of Philosophy degree in Physics from the University of California, San Diego (UCSD) in 1980. I have been a Research Physicist at the Center for Astrophysics and Space Sciences (C.A.S.S.) at UCSD from 1980 to present. My research has focused on analyzing mid-Infrared astronomical images for studying active galaxies and QSOs (quasi-stellar objects or quasars). In support of my research, I have also done work in the areas of Infrared instrumentation, radiative transfer and image reconstruction.

3. In 1992 I began working with C.A.S.S. graduate student Robert Piña to develop a new approach to improve mid-Infrared astronomical images collected with some of the first array cameras developed at UCSD. The goal was to remove the diffraction pattern of the telescope without generating "artifacts," or untrue glitches in the image resulting from human manipulation, commonly seen with other image-reconstruction techniques. The resulting method utilizes the fundamental informational elements of an image, or Pixons® ("pix" for picture and "on" for fundamental element, as in proton or electron) rather than pixels, which are only the fundamental physical units within an image grid. At this time, the "Pixon® method" was directed exclusively to reconstruction of astronomical images. A

patent application covering the Pixon® method was filed in May 1993, with Patent No. 5,912,993 ultimately issuing in 1999. Because the Pixon® method was developed in conjunction with my research at UCSD, this patent is assigned to The Regents of the University of California. Over the period of 1993 to 1995, I co-authored a number of manuscripts and conference presentations with Mr. Piña in which we described the Pixon® method and its application to astronomical image reconstruction. Attached hereto as Exhibit A is a representative listing of publications which I have authored and co-authored.

4. Once Dr. Piña received his Ph.D., he left UCSD to take a post-doctoral position in the astronomy department at University of Florida (Gainesville). From the time he left UCSD, Dr. Piña did not collaborate on any further development of the Pixon® method.

5. In 1995, I began to work with Amos Yahil, an astrophysicist in the Department of Physics and Astronomy at State University of New York at Stony Brook on the development of a technique for accelerating the Pixon® method to reduce the long processing times that were required by the original Pixon® method. This development work was conducted pursuant to an agreement between our respective university employers and was funded, at least in part, by grants from NASA and the U.S. Department of Energy for applications in image processing. A patent application covering the accelerated Pixon® method for image and signal processing was filed in June 1999. This application was assigned to The Regents of the University of California. Patent No. 6,353,688 issued March 5, 2002. A continuation application was filed on August 22, 2001 with claims drawn to the procedure for generating the Pixon® map for use in image reconstruction. This application issued as Patent No. 6,490,374 on December 3, 2002. (While the '374 patent names myself and Amos Yahil as inventors, it was determined during preparation of a second continuation application that because the claims covered the basic concept for generating a Pixon® map that Robert Piña had been

inadvertently omitted as an inventor. The appropriate paperwork is being prepared to add Dr. Piña as an inventor on this patent.) A second continuation application, Serial No. 10/308,450, which names myself, Dr. Yahil and Dr. Piña as inventors, was filed on December 2, 2002 with claims drawn to generation of a Pixon® map for use in extraction of data from a signal. This application is now pending. Each of these applications relates to images or signals which have a structure that permits location to be determined for generation of the map.

6. In 1997, Dr. Yahil and I obtained a license from The Regents of the University of California for use of the Pixon® method as covered by the patents identified above. We formed a new company under the name Pixon LLC to commercialize the Pixon® method. Our original and primary focus has been on the area of image reconstruction for application to military reconnaissance and surveillance images, medical images and other image applications. Working at Pixon LLC, we developed an algorithm and software for a much faster, nearly real time, image processing method. In order to provide video rate speed, a different image processing method was developed using the Pixon® map. This new algorithm and software were developed by myself and Dr. Yahil solely at Pixon LLC's own time and expense. The new method was disclosed to licensing officers at UCSD and no claim to the invention has been made on behalf of the University. The revised Pixon® method is the subject of pending application Serial No. 10/041,253, filed January 4, 2002, which is assigned to Pixon LLC.

In 1999, Pixon, LLC sought and obtained an SBIR grant from NASA for conceptual development of hardware for real time processing of video images using the revised Pixon® method. I obtained a written release from the director or C.A.S.S. at UCSD to devote at least 50% of my time to working for Pixon LLC on development of the subject matter of the grant. All work on under this grant has been performed separate and apart from UCSD.

7. In late 1996, while conducting further development work on image processing applications, Dr. Yahil and I conceived a method for processing abstract data based on the principle of minimum complexity for application to algebraic problems, i.e., problems in which the signal cannot be identified with a location. The Algebron® method is fundamentally different from the Pixon® method because it is not possible to generate a map from the abstract variables, whereas the Pixon® method requires a kernel map to be generated. If one were to attempt to form a map by plotting the data on a chart or graph, external information would be added which could bias the analysis and produce inaccurate or incomplete results. The goal of the Algebron® method is to avoid introduction of external information, making the prediction based on the input data alone. At Pixon LLC, we began to develop the Algebron® method and software for application to economic forecasting. Pixon LLC neither sought nor received any government grants or other external funding for development of the Algebron® method. The Algebron® method was disclosed to licensing officers at UCSD and no claim to the invention has been made on behalf of the University. In September 1999, a patent application (Serial No. 09/404,122) for the Algebron® method was filed. This application is assigned to Pixon LLC.

8. In or around late 2000, Dr. Piña and I discussed some of the work we were doing at Pixon LLC. At that time I told him about the Algebron® method. This was the first time I had ever discussed the Algebron® method with Dr. Piña. He could not have had anything to do with the conception or development of the Algebron® method because he knew nothing about it until two years after the patent application for the Algebron® method was filed.

9. One of the listed articles in Exhibit A, published in *The International Journal of Image Systems and Technology*, is entitled "Pixon-Based Multiresolution Image Reconstruction and the Quantification of Picture Information Content" (1995 -- Puetter Paper #2 as identified in the Office Action.) This article deals exclusively

with imaging. The journal in which it is published is devoted entirely to research, development and applications in imaging. All commentary in this article, including the excerpt which reads:

> ...we hope to demonstrate that pixon-based methods have consequences and implications for fields outside of image restoration/construction , including data compression and information theory.

relates solely to imaging. This text is intended to convey the idea that the Pixon® method may also have applications in the areas of image data compression and information theory of images. Nothing broader was intended, and it would be readily apparent to someone in the imaging field that this text described other possible image processing applications since both data compression and information theory are commonly applied to image data. For example, see, e.g., J. Kim, et al., "Nonparametric Methods for Image Segmentation Using Information Theory and Curve Evolution", *2002 IEEE International Conference on Image Processing*, Rochester, NY, Sept. 2002, which is attached hereto as Exhibit B.

I wrote the text quoted from Puetter Paper #2 to mean that, in addition to image reconstruction, image data can be compressed or the image data can be encoded into a signal for transmission and/or reception using data compression and information theory, respectively. There was no intention to suggest that the Pixon® method would have applications to analysis of abstract data having no geometric structure. In fact, the Pixon® method would not work for analysis of multiple, co-varying abstract variables because abstract variables have no location, and location of the signal is essential.

10. The abstract of Puetter Paper #2 reads as follows:

> This paper reviews pixon-based image reconstruction, which in current formulation uses a multiresolution language to quantify an image's Algorithmic Information Content (AIC) using Bayesian techniques. Each pixon (or its generalization, the informaton) represents a fundamental quanta of an image's AIC, and an image's

> pixon basis represents the minimum degrees-of-freedom necessary to describe the image within the accuracy of the noise. We demonstrate with a number of examples that pixon-based image construction yields results consistently superior to popular competing methods, including Maximum Likelihood and Maximum Entropy methods. Typical improvements include higher spatial resolution, greater sensitivity to faint sources, and immunity to the production of spurious sources and signal correlated residuals. Finally, we show how the pixon provides a generalization of the Akaike information criterion, how it relates to concepts of "coarse graining" and the role of the Heisenberg Uncertainty Principle in statistical mechanics, provides a mechanism for optimal data compression, and represents a more optimal basis for image compression or reconstruction than wavelets. (emph. added.)

Looking at the full text of the abstract, in which the word "image" appears 7 times, it is clear that I was writing only about images. The mention of (1) Bayesian techniques of Algorithmic Information Content (AIC) and (2) Akaike Information Criterion cannot simply be taken out of the context in which I used them. Both methods are well known in the field of statistical mechanics. Akaike's Information Criterion is a standard tool in time series model fitting, and its computation is available in many time series programs. Thus, it is not surprising that it is one of the tools in the GARCH Toolbox since the GARCH Toolbox is all about univariate time series modeling. We don't claim to have invented these techniques. The fact that I have incorporated these widely-used methods in a statistically-based approach to image reconstruction does not mean that all subsequent applications of these same statistical methods automatically flow from or obvious from this description. Puetter Paper #2 is about image reconstruction in which images have a geometric structure that can be decomposed into smaller units, each having a location within the overall image grid. The Algebron® method deals with multiple, co-varying abstract variables which cannot be decomposed in a similar manner. Neither Bayesian techniques of AIC nor Akaike's Information Criterion address this issue. The Pixon® method and the Algebron® methods are fundamentally different and selected words in the text of Paper #2 should not be taken out of context in an effort to make them seem the same.

11. I declare under penalty of perjury under the laws of the United States that the foregoing is true and correct to the best of my information and belief.

Dated: August 22, 2003

R. Puetter

Richard C. Puetter